A User-Programmable Vertex Engine

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SIGGRAPH 2001

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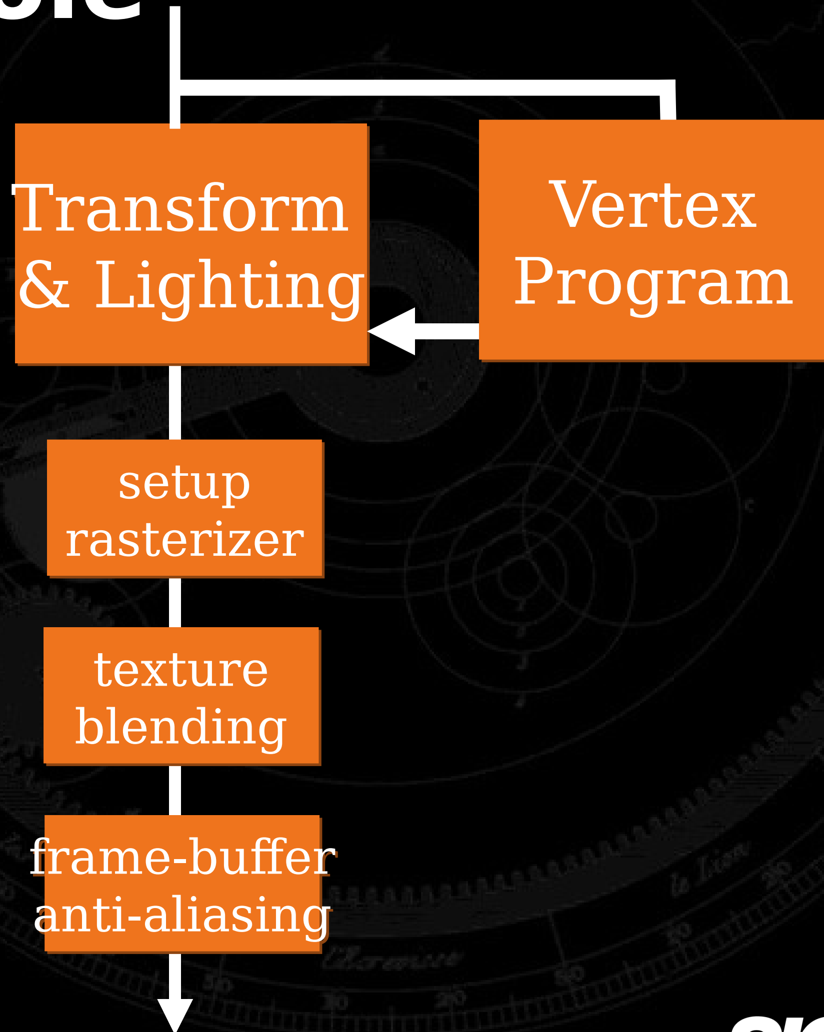
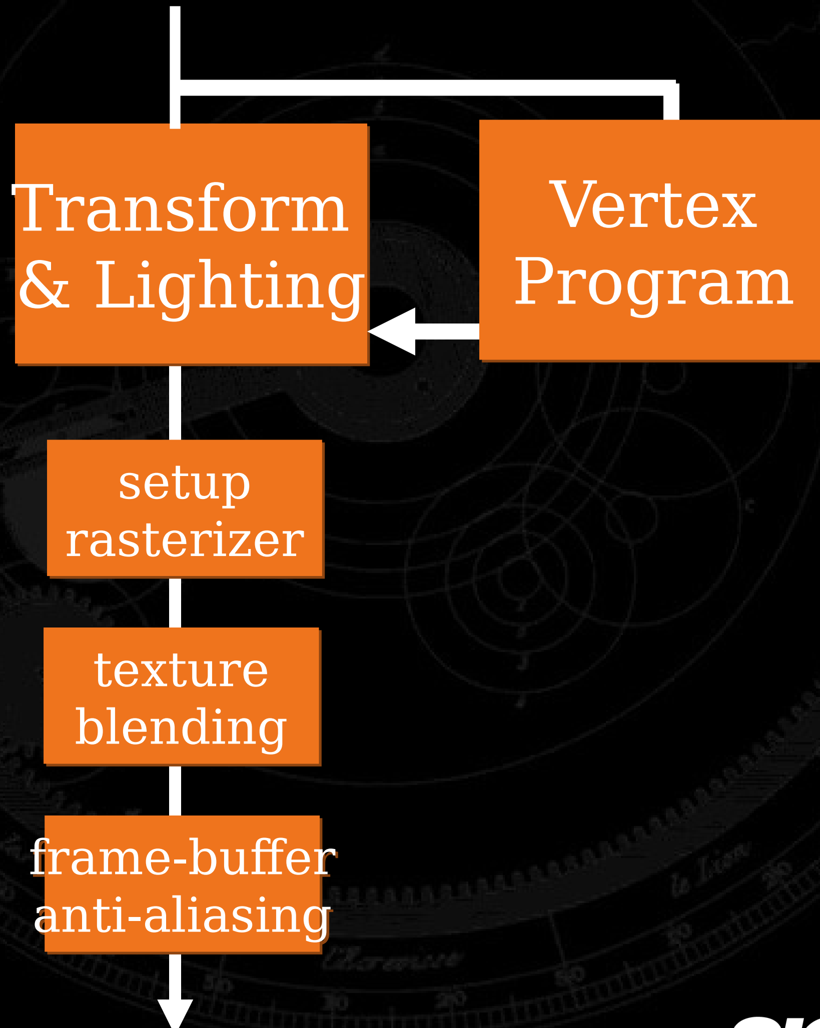
Introduction

- Programmability vs. Configurability
- Programmability is trend
- Very efficient vertex engine
- Simple yet powerful programming model
- Supports fixed function pipeline
- Delivered in the GeForce3

Pipeline Role



Same HW!



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Previous Work: Geometry Engine

- High bandwidth + lots of Flops
- Low clock rate
- No architectural continuity
- VERY hard to program
- Some high-level language support (maybe)
- A compromise solution (vtx,prim,pix, ...)

Alternative: The CPU

- Low bandwidth + reasonable Flops
- High clock rate
- Excellent architectural continuity
- VERY hard to use efficiently
- Excellent high-level language support
- Flexible, but often too slow

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New Design: The Vertex Engine

- Simple hardware for a commodity GPU
- Allows user to manipulate vertex transform
- Simple to use programming model
- Superset of fixed function mode

Why Vertex Processing?

- Very parallel
- Use single vertex programming model
- Hardware can batch or interleave
- KISS

Why Not Primitive Processing?

- Face culling and clipping break parallelism
- Complicates memory accesses
- Inefficient (control takes time)
- Let hardware designers optimize

Programming Model: Vertex I/O

- Streaming vertex architecture
- Source data converted to floats
- Source data loaded
- Run program
- Destination data drained
- Destination data re-formatted for hw

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Programming Model

Vertex Source
16x4 registers

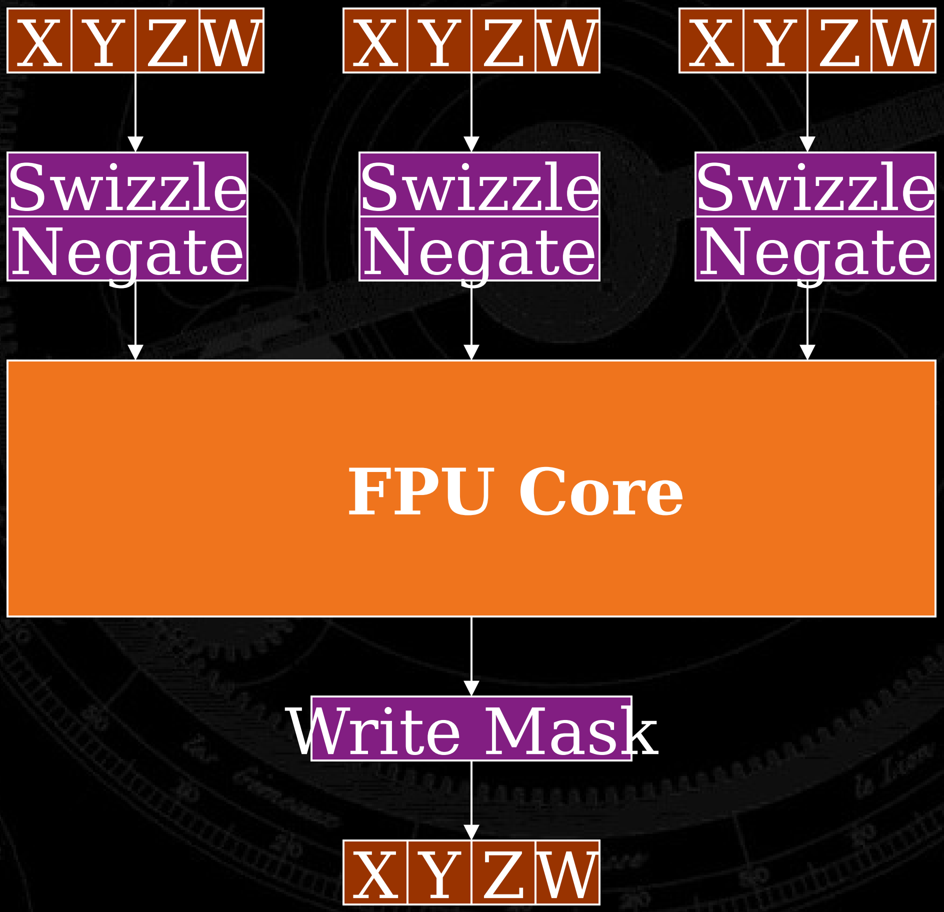
Vertex Program
128 instructions

Vertex Output
15x4 registers

Program Constants
96x4 registers

Temporary Registers
12x4 registers

Data Path



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Instruction Set: The Core Features

- Immediate access to sources
- Swizzle/negate on all sources
- Write mask on all destinations
- DP3,DP4 most common graphics ops
- Cross product is MUL+MAD with swizzling
- LIT instruction implements phong lighting

Cross Product Coding Example

```
# Cross product R2 = R0 x R1

MUL R2, R0.zxyw, R1.yzxw;
MAD R2, R0.yzxw, R1.zxyw, -R2;
```

Sample OpenGL Vertex Program

```
static const GLubyte vpgm[] = “\!!VP1. 0\
  DP4   o[HPOS].x, c[0], v[0];
    \
  DP4   o[HPOS].y, c[1], v[0];
    \
  DP4   o[HPOS].z, c[2], v[0];
    \
  DP4   o[HPOS].w, c[3], v[0];
    \
  MOV   o[COL0], v[3];
```

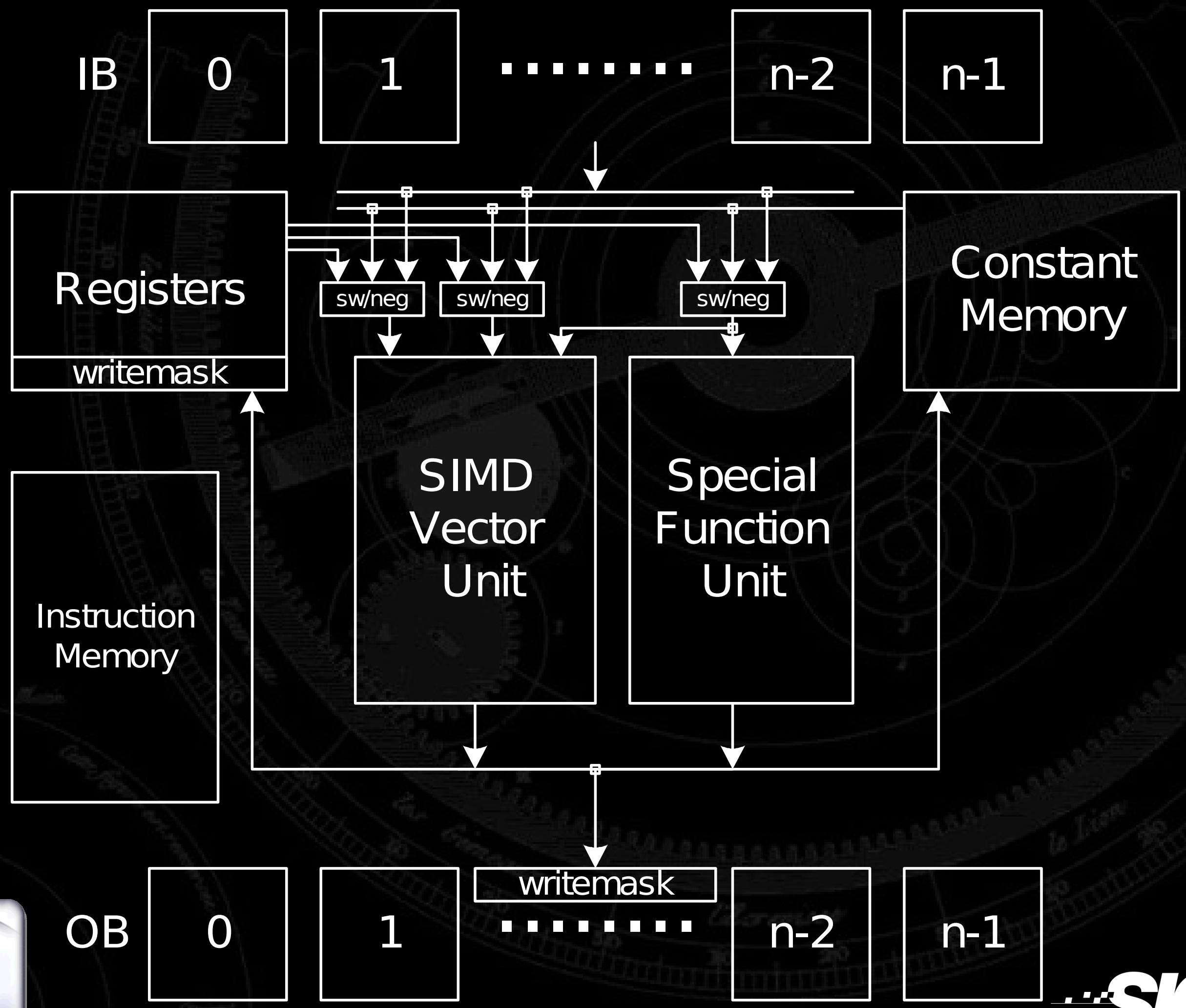
Instruction Set: The ops

- 17 instructions total
- ARL
- MOV, MUL, ADD, MAD, DST
- DP3, DP4
- MIN, MAX, SLT, SGE
- RCP, RSQ, LOG, EXP, LIT

Hardware Implementation

- Vector SIMD Unit + Special Function Unit
- Multithreaded and pipelined to hide latency
- Any one instruction/cycle
- All instructions equal latency
- Free swizzling/negate/write mask support

HW Block Diagram



API Support

- Designed to fit into OpenGL and D3D API’s
- Program mode vs. Fixed function mode
- Load and bind program
- Simple to add to old D3D and OpenGL programs

DEMOS

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Conclusion

- Very simple, efficient implementation
- Allows vertex programming continuity
- Stanford Imagine Architecture
- A work in progress, lots more to come…
- We welcome your feedback